Hydrostatic Water in Soil

CE 362: Geotechnical Engineering

By

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- Water strongly affects the engineering behavior of soils, especially fine grained soils, as well as rock masses.
- In general, Water in soils can be thought as either static or dynamic.
- GWT (groundwater table) is considered static for most engineering practice (even though it is changing throughout the years)

6.2 Capillarity

- Capillary is the rise of water in thin tubes due to surface tension. In soils, it occurs between surfaces of water , grains, and air.

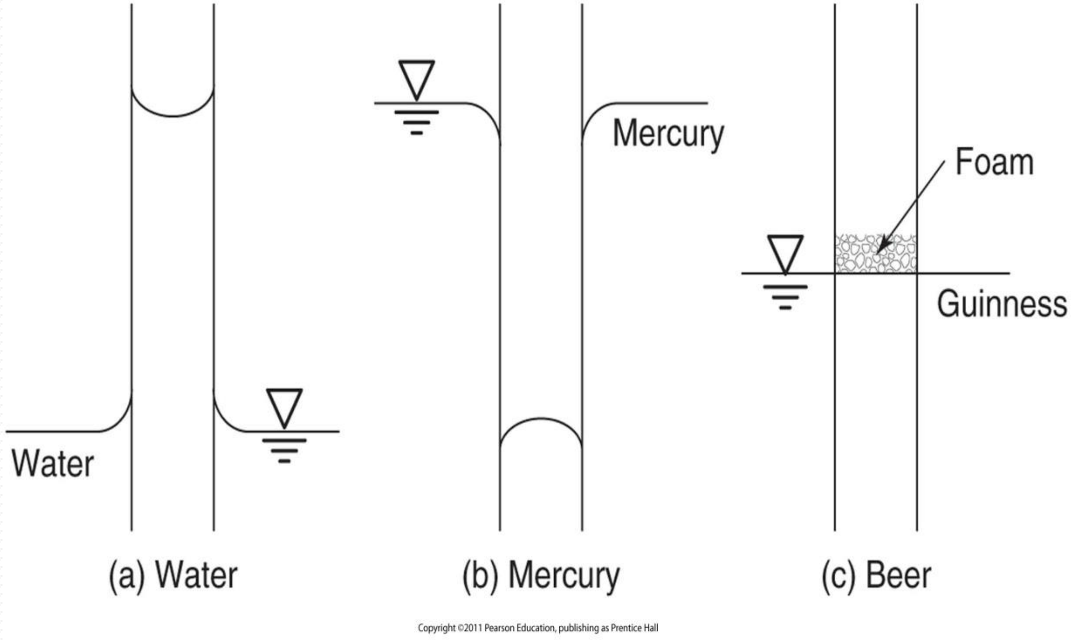


FIGURE 6.1 Menisci in glass tubes in (a) water, (b) mercury, and (c) beer.

Capillary Model

In capillary zone, water Pressure is in tension (negative Pressure). Soil in cap. Zone is fully saturated

$u_c = -\gamma_w Z$

Below water surface, Water pressure is compression

$u_c = \gamma_w Z$

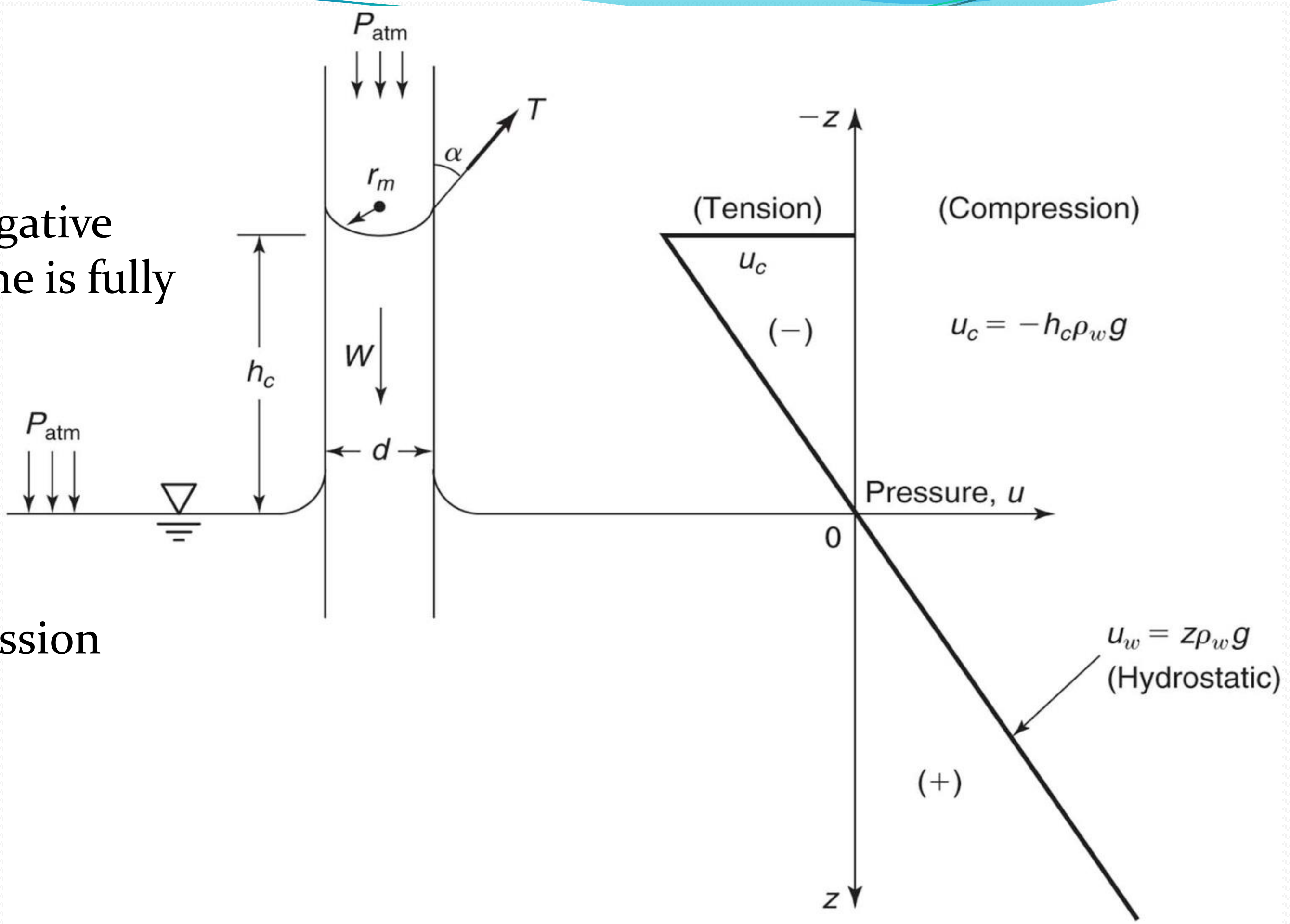


FIGURE 6.2 Meniscus geometry of capillary rise of water in a glass tube.

Capillary rise in Soils

- Water arise in soils through the voids. As the size of pores decreases (the size of particles decreases), the capillary rise in soil (hc) increases.

Terzaghi et al. (1996) suggested an equation for the capillary rise of water in soils:

$$h_c = \frac{C}{e\,D_{10}}$$

C: empirical coeff. Varies between 0.01 and 0.05
hc = capillary height (m)
e = void ratio
D10: effective diameter (mm)

TABLE 6.1 Approximate Height of Capillary Rise in Different Soils

	Grain Size Range (mm)	Loose	Dense
Coarse sand	2–0.6	0.03–0.12 m	0.04–0.15 m
Medium sand	0.6–0.2	0.12–0.50 m	0.35–1.10 m
Fine sand	0.2–0.06	0.30–2.0 m	0.40–3.5 m
Silt	0.06–0.002	1.5–10 m	2.5–12 m
Clay	< 0.002	≥ 10 m	

After Beskow (1935) and Hansbo (1975 and 1994).

6.9 Intergranular or effective stress

- Effective stresses between soil particles was introduced by Terzaghi in 1923.
- Effective stresses in soils are responsible for soil compressibility and shear strength. For evaluating soil strength and settlement, we consider soil effective stresses.

$$\sigma = \sigma' + u$$

$$\text{or } \ \sigma' = \sigma - u$$

where

σ : Total normal stress on the contact area

σ' : Intergranular or Effective normal stress on the contact area

u : pore water pressure

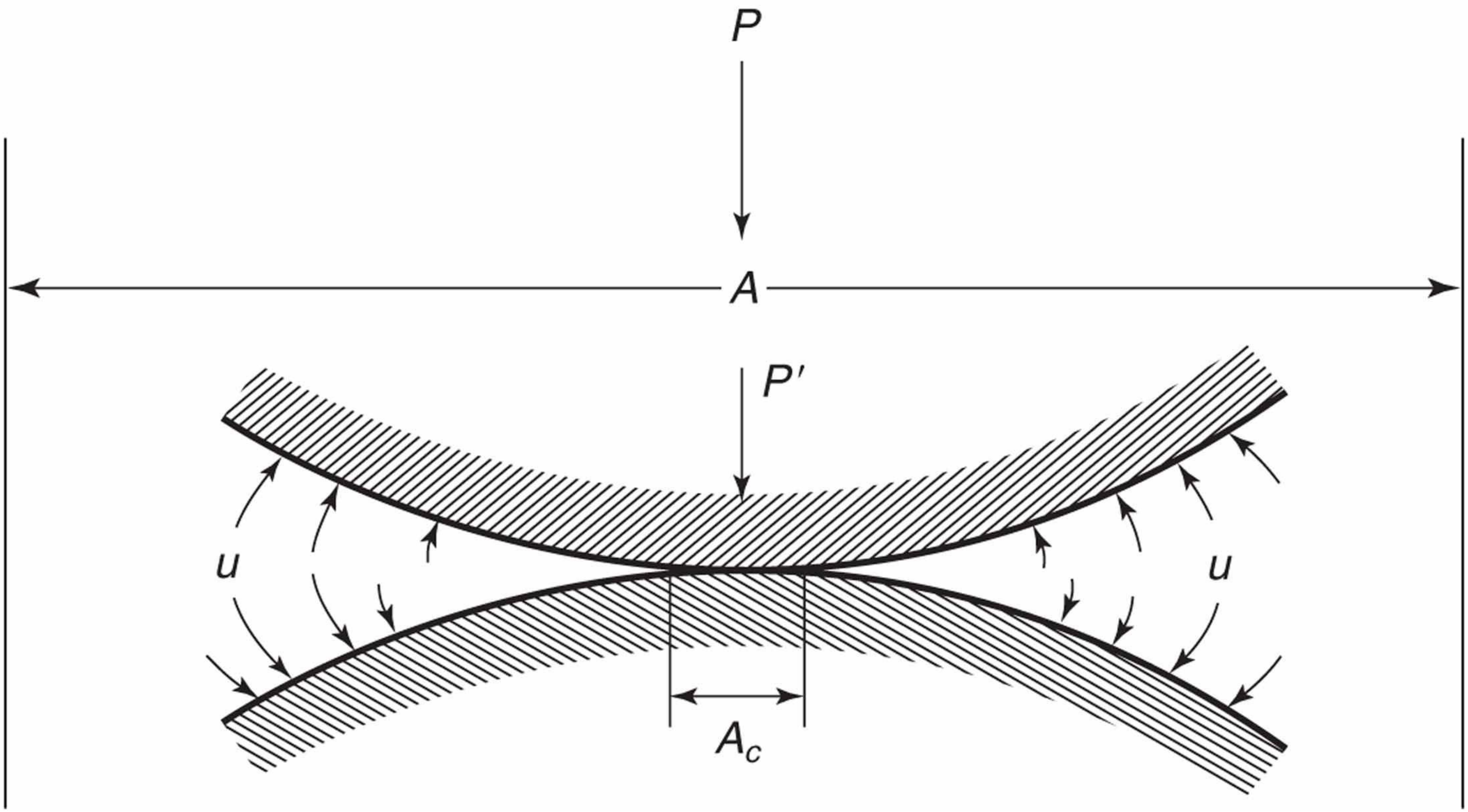
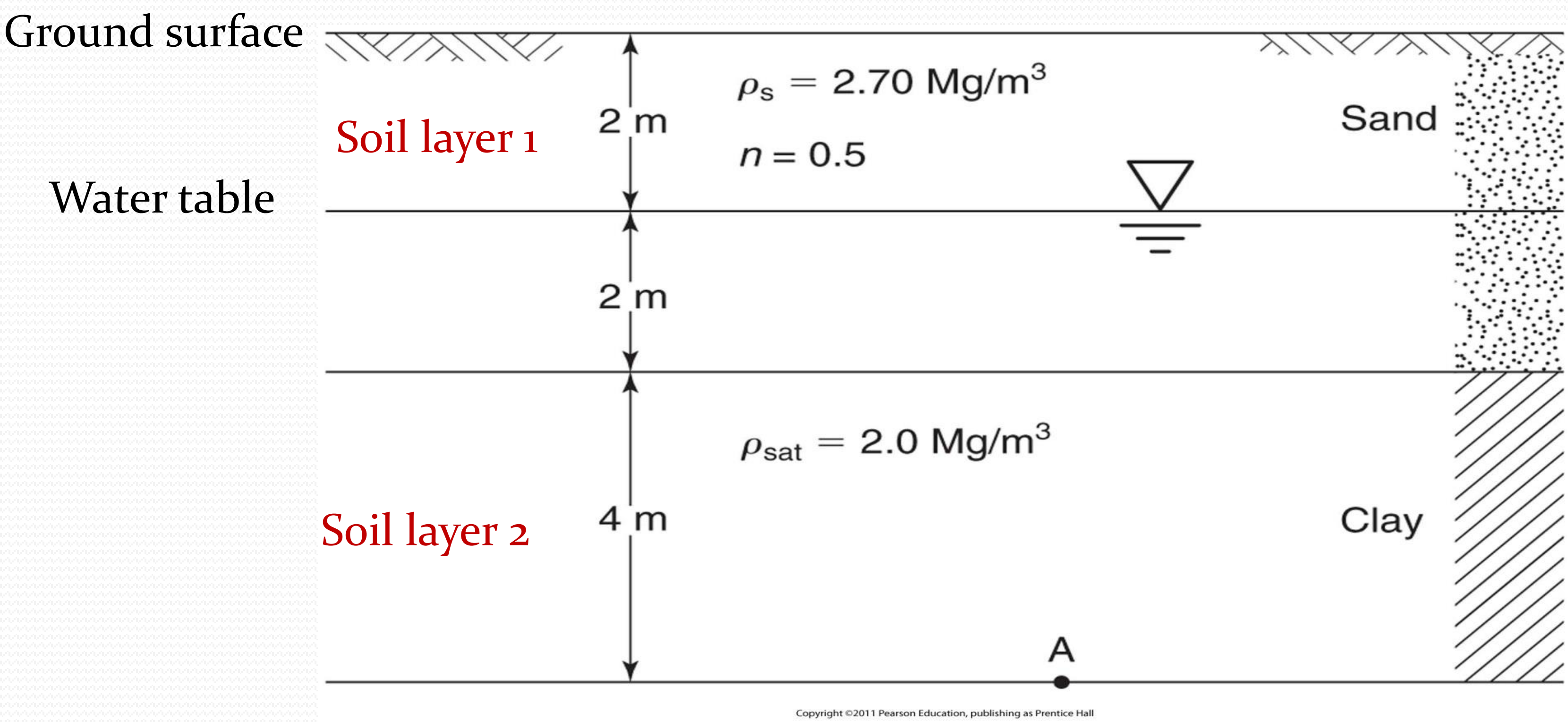


FIGURE 6.31 Particles in solid contact (after Skempton, 1960).

6.10 Vertical Stress Profiles

- When the densities and thicknesses of soil layers and level of water table are known, then the total stress, pore water pressure, and effective stresses can be evaluated at any depth.

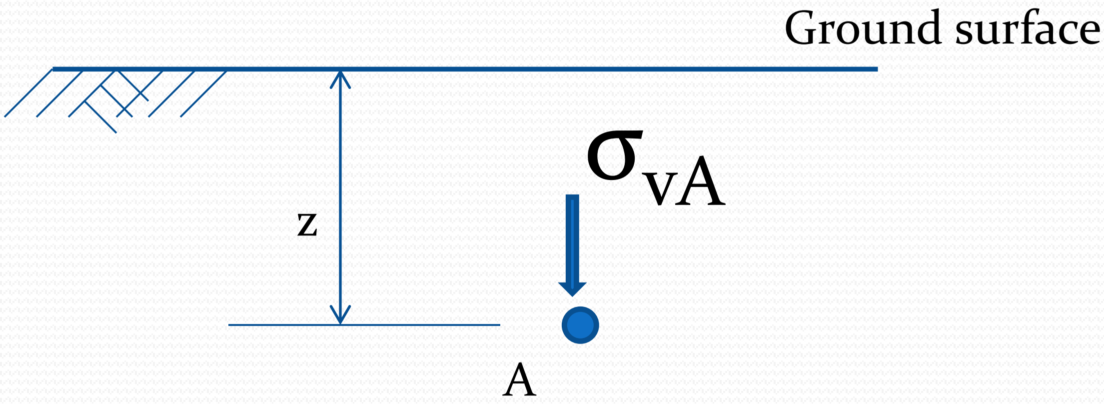


For homogenous soils (*γ is constant with depth*)

The vertical stress at a point in the soil mass is

$$\sigma_{vA} = \gamma z$$

$\gamma = \rho g$ = *unit weight of soil*

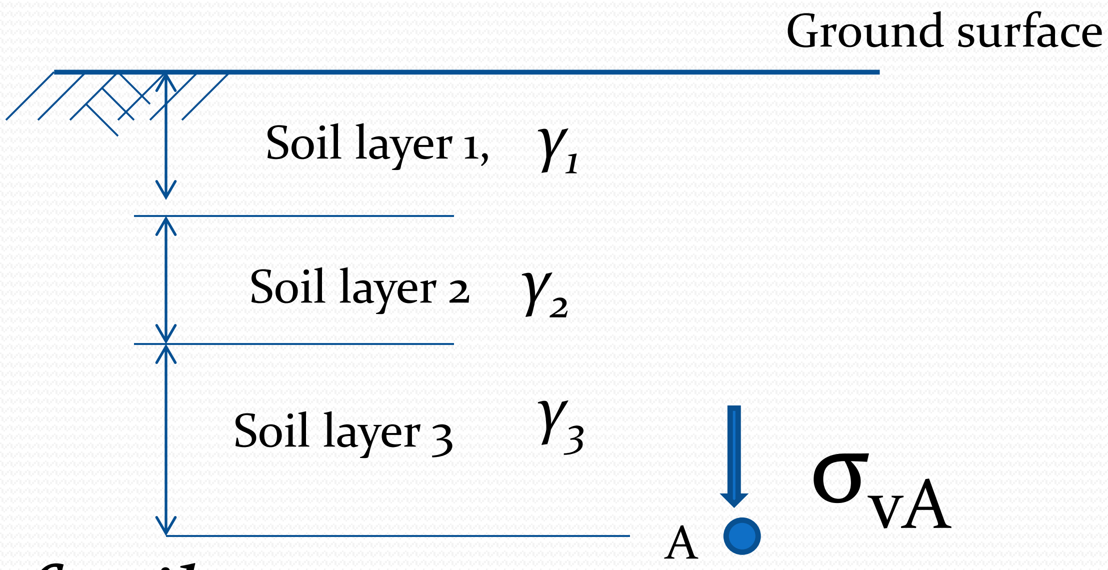


For layered soil

$$\sigma_{vA} = \Sigma \gamma z$$

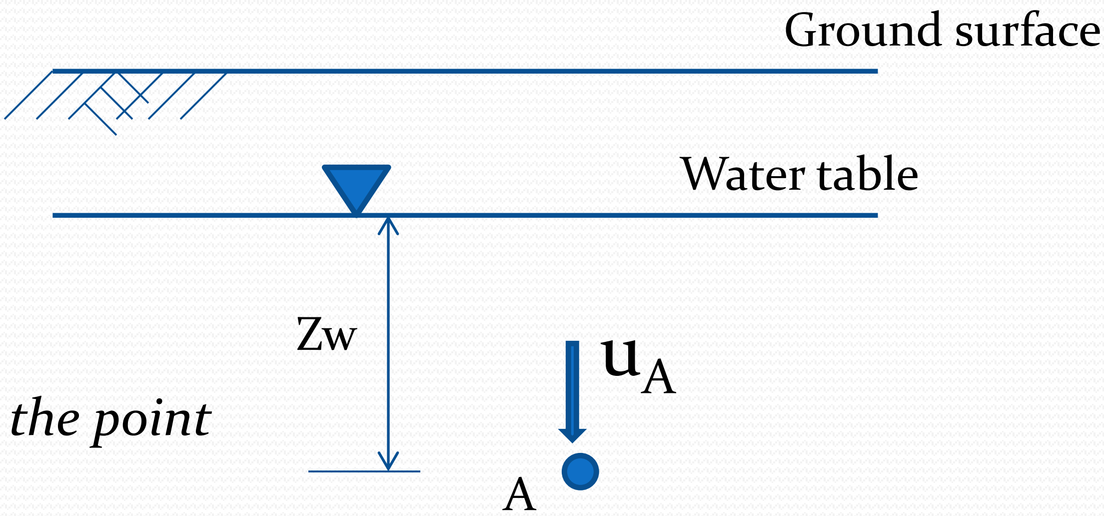
$$\sigma_{vA} = \gamma_1 z_1 + \gamma_2 z_{2+} \gamma_3 z_3$$

$\gamma = \rho g$ = *unit weight of soils*



Pore water pressure (neutral pressure), u_A

$$u_A = \gamma_w z_w$$



γ_w *unit weight of water,*
z_w *the depth below water table to the point*

The effective vertical stress at point A will be

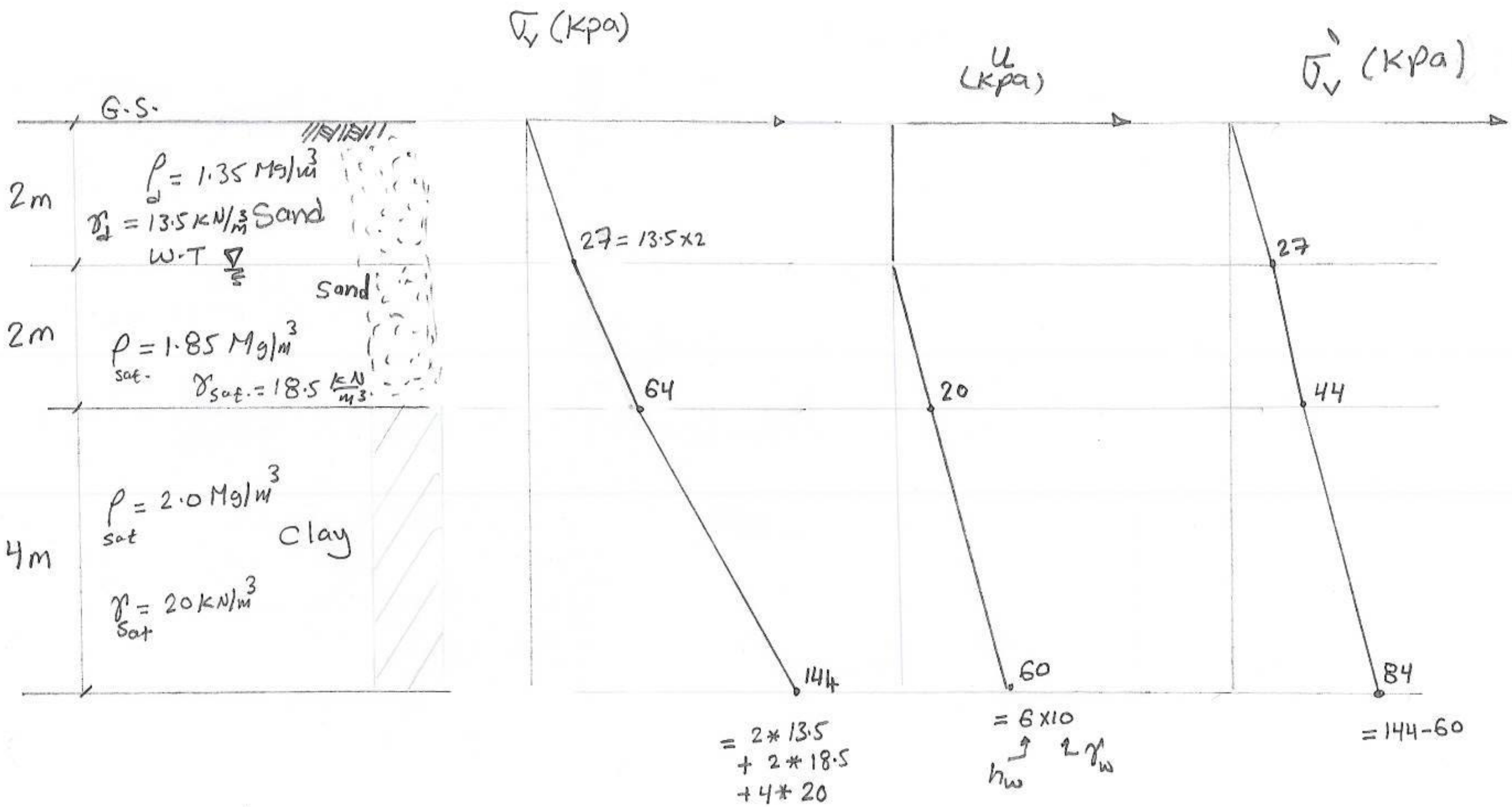
$$\sigma'_{VA} = \sigma_{VA} - u_A$$

EX. 6.9

For the soil profile shown, Draw with depth:
Total Stress, Pore water pressure, and effective stress.

Use $\gamma_w = 10\,kN/m^3$

$g = 10\,m/s^2$

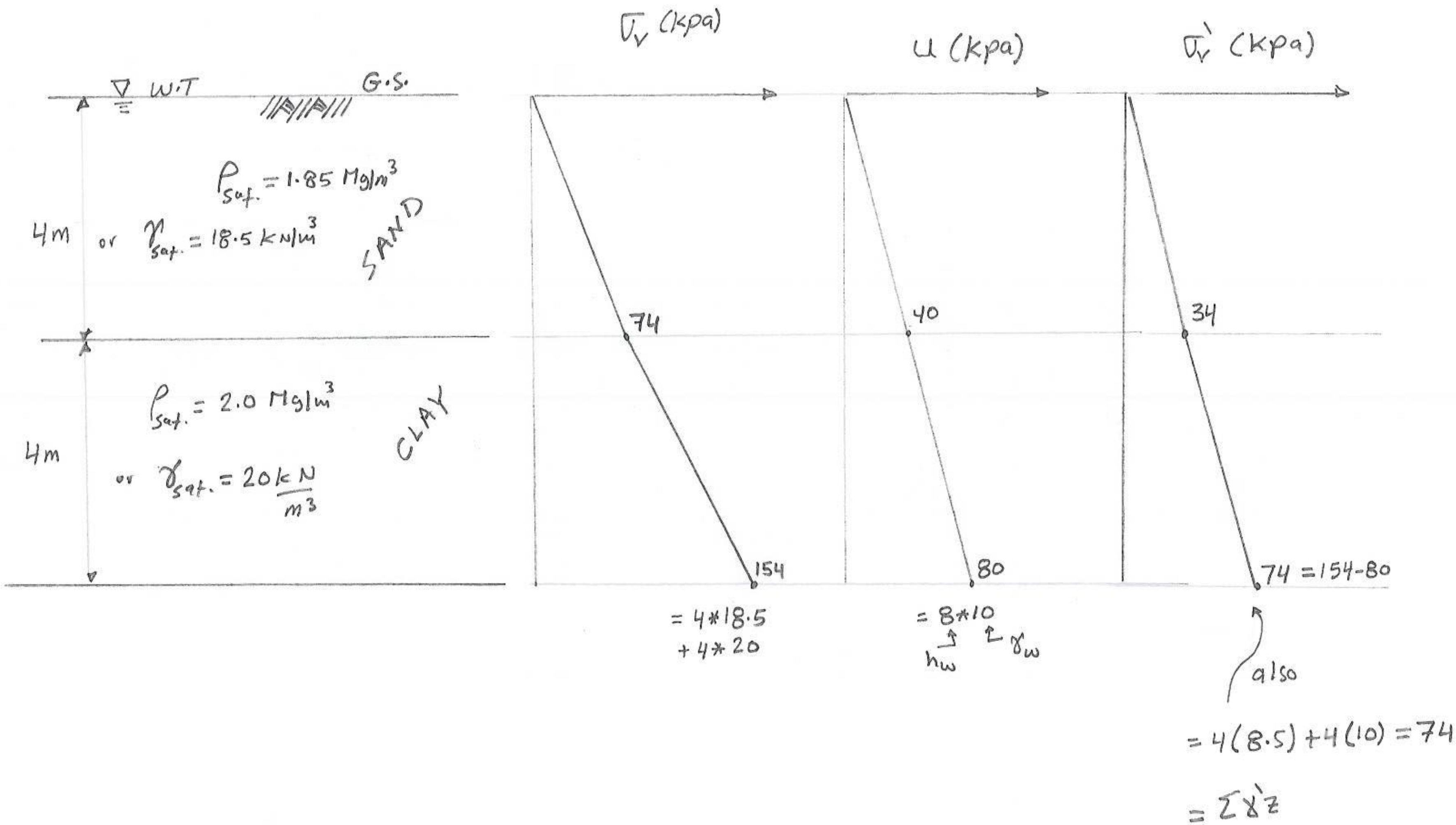


Note: $\sigma'_v = \sigma_v - u$

or $\sigma'_v = \sum \gamma' z$, $\gamma' = \gamma - \gamma_w$

Ex. 6.10

For the soil profile show, draw with depth,
σ_v, u, & σ_v'. Use $\gamma_w = 10\ kN/m^3$, $g = 10\ m/s^2$

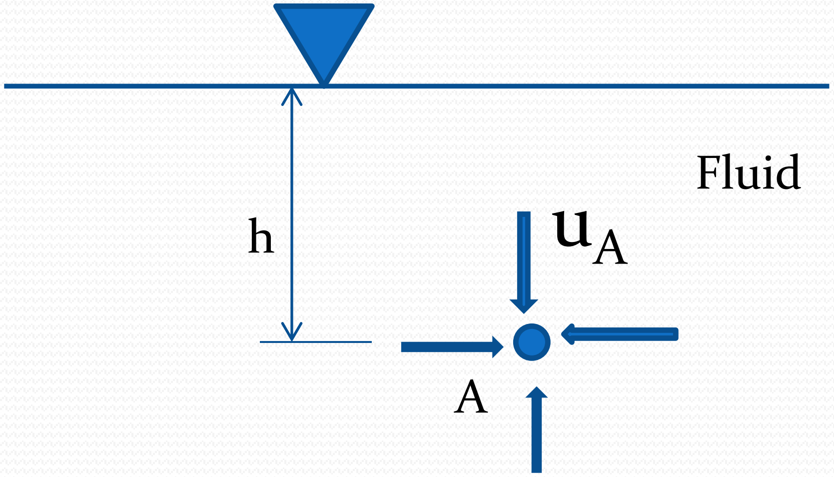


6.11 Relationship between Horizontal and Vertical Stresses

- From Hydrostatics, the pressure in a liquid is the same in all directions.

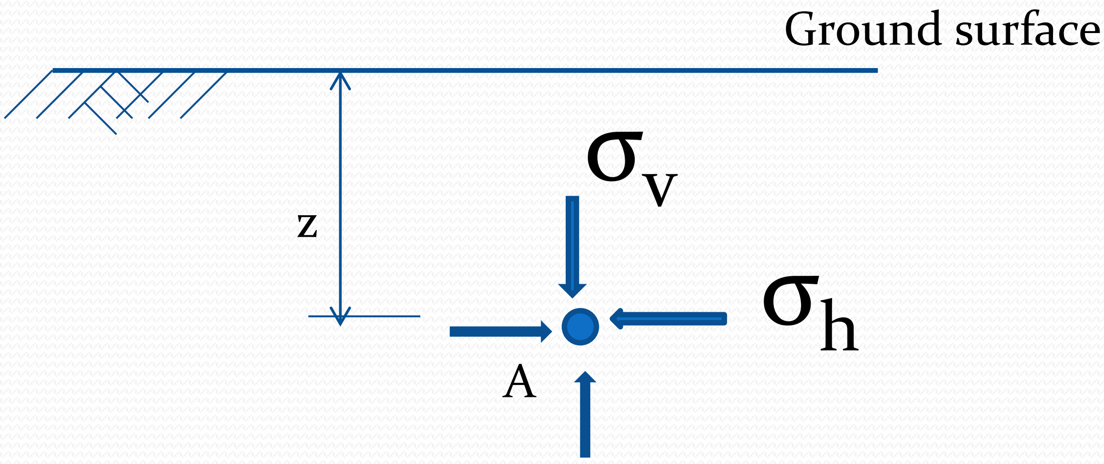
Fluid pressure at point A, u_A is the same in all directions.

$$u_A = \gamma h$$



- In soils the ground horizontal stresses are always different than the vertical stresses. (Stresses in situe are not necessarily hydrostatic).

$$\sigma_h = K\sigma_v$$



σ_v : Vertical stress

σ_h : Horizontal stress

K : Lateral earth pressure coefficient

In terms of effective stresses

$$\sigma'_h = K_o \, \sigma'_v$$

σ'_v : Effective Vertical stress

σ'_h : Effective Horizontal stress

K_o : Coefficient of Lateral earth pressure at rest

K_o : 0.4 or 0.5 for sedimentary soils that have never preloaded and up to 3.0 or more for heavily preloaded soils (over consolidated soils).

HW 4

- Q 6.28
- Q 6.33
- Q 6.36